FLUSHING PROCESS FOR TREATING WASTE MATERIAL

BACKGROUND OF INVENTION

The present invention relates to an improvement of prior known processes for processing compacted cellulosic fiber containing waste material (i.e. baled material or material in which the baling wires have been broken or loose material which has been compacted) for recovery of high quality cellulosic fibers from waste material which usually constitutes waste paper.

As discussed at some length in our prior patents 5,217,805 and 5,496,439, before subjecting waste material containing cellulosic fibers to fibrillation stresses in a pulper, digester or slusher, it has been practice to impregnate the cellulosic fiber-containing waste material with a ~~debonding fiber~~ softening and swelling liquid in a closed pressure chamber under partial vacuum conditions which produces a fiber-containing-liquid pulp of which the length and conditions of the cellulosic fibers are not seriously negatively affected by the fibrillation stresses of the pulpier.

The action of the partial vacuum condition has been to partially remove (or evacuate) the majority of the air from within compacted cellulosic fiber containing waste material and to replace the partially removed air with a debonding and fiber softening and swelling liquid. It was learned that the deeper the partial vacuum the more the liquid impregnated the cellulosic fiber-containing waste material and the more extensive and effective the treatment. Contrary-wise it was also learned that the depth of the partial vacuum applied must be limited to avoid deleterious evaporative drying of the

cellulosic fibers. The action is described as: Air Removal (or Evacuation)/ Liquid Replacement.

BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 comprises two graphs illustrating the quality of cellulosic fibers based on the Tear and Tensile strengths of the sheets they form.

Fig. 2 is a plot of the Tear Factor versus Breaking Length of the sheets formed of the fibers produced by our present invention and by prior inventions.

Fig. 3 is a schematic illustrating in part the process that is claimed.

Fig. 4 is a plot of Air in Compacted Waste Paper.

Fig. 5 is a plot of Domains of Effectiveness of Prior "Remove & Replace" Inventions and of the New "Circulate, Flush & Refresh" Invention.

Table I. is a listing of the measurements for, of the computational steps and results of Air in Compacted Waste Paper.

SUMMARY OF INVENTION

The object of this invention is to recover high quality cellulosic fibers from compacted cellulosic fiber-containing waste material. This is accomplished by confining the waste material in a debonding fluid-filled closed chamber and consecutively adding debonding fluid to the closed chamber and removing debonding fluid from the closed chamber. The debonding fluid that is removed from the closed chamber may be partially spent. It has been observed that there is a partial collateral loss of air from the compacted fiber-containing waste material and subsequently from the closed chamber during the process steps in which debonding fluid is removed.

DETAILED DESCRIPTION OF THE INVENTION

Four pulp properties principally affect the strength quality of paper and paperboard produced from the pulp: fiber length, fiber strength, fiber-to-fiber bond strength per unit of fiber-to-fiber contact area and fiber-to-fiber conformability. Tensile strength is dependent on fiber strength, fiber-to-fiber bond strength per unit of fiber-to-fiber contact area and fiber-to-fiber conformability; the greater each of these, the greater is the tensile strength. Out-of-plane tear strength (Elmendorf Tear) is primarily dependent on fiber length; the longer the fiber length, the greater is the out-of-plane tear strength. However tear strength can be adversely affected by the extent of bonding in paper/paperboard. The greater the tear strength at a given level of tensile strength, the greater the fiber quality. The graphs of Fig. 1 illustrate the quality comparisons of

fiber based on Tear and Tensile. The choice of the two graphs is dependent on the fiber species.

Because the standardized measurements of tear and tensile are affected so differently by the four pulp properties, taken together they are very effective in portraying pulp fiber quality. The greater the pulp quality, the less refining is required to comply with tensile strength related specifications of paper and paperboard grades. The less refining required, the less pulp fiber fines are generated and drainage on the paper machine is less retarded. The greater the drainage, the greater the potential for faster paper machine speed and higher production and the less the need for costly dry strength additives such as starch.

Subsequent to the laboratory work reported in our Patent 5,496,439, which produces a cellulosic fiber-containing pulp by subjecting the cellulosic fiber-containing compacted waste material to consecutive negative and positive gage pressure conditions in the debonding liquid-filled pressure chamber, further laboratory work has been conducted comparing these prior art results to the pulp produced by subjecting compacted cellulosic fiber-containing material to consecutive additions and removals of debonding liquid in a debonding liquid-filled, closed chamber.

Figure 3 illustrates schematically the procedure in which air in the compacted cellulosic fiber containing waste material acts in concert with the addition and removal of the debonding liquid to flush the debonding liquid in and out of the compacted material.

In Figure 3 the air within the compacted material is shown schematically as initially and principally distributed throughout the compacted waste material . After subsequent cycles of circulating, flushing and partial refreshing of debonding liquid in

and out of the compacted material the distribution of the air depends on its initial locations in the compacted waste material.

A first part of the air is located in the interstices within the cellulosic fibers that are distributed throughout the compacted waste material. A second part of the air is located in the interstices between the cellulosic fibers and remains largely distributed throughout the compacted waste material with greater concentration towards the center of the compacted waste material after cycles of adding debonding liquid to and removing debonding liquid from the closed chamber. A third part of the air is located in the interstices between the sheets and pieces of the compacted waste material; its distribution is largely skewed after cycles of adding debonding liquid to and removing debonding liquid from the closed chamber with substantially more of the remaining third part of the air near the center of the compacted material. Collaterally a substantial portion of the third part of the air is flushed out of the compacted waste material by the cycles of adding debonding liquid to and removing debonding liquid from the closed chamber. Figure 3 illustrates the collateral loss of some of the air. Collaterally less of the second part of the air is flushed out of the compacted waste material by the cycles of adding debonding liquid to and removing debonding liquid from the closed chamber. Collaterally still less of the first part of the air is flushed out of the compacted waste material by the cycles of adding debonding liquid to and removing debonding liquid from the closed chamber. The scale of Figure 3 does not allow illustration of the lesser collateral losses of the first and second parts of the air.

Our invention thereby circulates and flushes debonding liquid in and out of the compacted waste material structures by one or more cycles of adding debonding liquid

to and removing debonding liquid from the closed chamber and relying on the trapped air in the compacted waste material to act as miniature expelling pumps to circulate, flush and partially expel the debonding liquid containing partially consumed debonding chemical(s) and replacing in part the partially spent treating fluid with fresher debonding liquid. Paper and paper fiber tend to be acidic and neutralize the debonding fluid. By partially replacing the partially neutralized debonding liquid with fresher debonding liquid, originally weaker debonding liquid can be utilized.

Other patented processes including our U.S. 5,217,805 and U.S. 5,496,439 utilize the combination of partial vacuum to remove as much air from waste material containing waste paper and high pressure to force as much debonding liquid into the partially void interstices in the waste paper and cellulosic fibers as results in optimal paper mill operations. Optimal operations are determined by tradeoff of effectiveness of swelling and debonding of the cellulosic fiber, and capital and operating costs and rate of production of process equipment. The depth of partial vacuum is limited by deterioration of fiber properties by evaporative drying of cellulosic fiber.

Other processes remove air and replace with debonding liquid. Our new invention utilizes air that is retained within the compacted waste material in combination with addition of debonding liquid to and removal of debonding liquid from a closed chamber containing waste material containing waste paper to flush and circulate through and partially refresh within the waste material containing waste paper containing cellulosic fibers.

In our improved process the compacted material is consecutively filled with additional debonding liquid causing the air within the compacted material to be

compressed and occupy less space and the debonding liquid to occupy the space vacated by the air. Upon removal of debonding liquid the first part of the air that was compressed within individual fibers expels the debonding liquid outwardly through the fiber and the second part of the air that was compressed between the fibers is flushed through and between adjacent fibers and the third part of the air flushes the debonding liquid through the paper and causes circulation, exchange and repositioning within the large interstices within the compacted material and expels partially out of the compacted material. Along with the partially spent debonding liquid from within the compacted material that is partially expelled there is collateral loss of air from within the compacted material. The air that is lost in principally the third part of the air along with less of the second part of the air and still less of the first part of the air. Successive cycles of addition of debonding liquid to and removal of partially spent debonding liquid from the closed chamber and consequently to and from the compacted material adds fresher debonding liquid to and removes partially spent debonding liquid from the cellulosic fiber contained in the compact material providing a fresher debonding liquid to swell and debond the cellulosic fibers more effectively. An advantage is the use of a lower concentration of debonding liquid and associated reduction of requirements to neutralize the residual debonding liquid down stream in the pulping and papermaking process.

In summary our new invention FLUSHES, CIRCULATES and REFRESHES; previously existing processes REMOVE(or EVACUATE) and REPLACE.

There are applications of greater effectiveness of these two different processes. Remove and Replace are more effective debonding waste paper containing cellulosic

fibers that are most difficult for debonding liquid to reach and contact. Milk Carton and Drink Boxes are examples.

Flush, Circulate and Refresh are more effective debonding waste paper containing cellulosic fibers that are less difficult for debonding liquid to reach and contact. OCC is a large market volume example.

An example of the use of our invention is its application to the repulping of Old Corrugated Containers (OCC). OCC is composed of liners or facings and fluted medium. The liners are normally chemically sized to aid in stiffness retention under mildly wet conditions. Sizing additives reduce the ability of fiber to swell under wet conditions.

Our invention addresses the affects of these anti-swelling additives by flushing and circulating weak caustic solution in and out of the compacted OCC to partially expel the partially spent weak caustic solution containing the swelling additives and to partially exchange the partially spent caustic solution with fresher caustic. Also, the caustic that is used to swell the fibers is partially exchanged with fresher caustic solution. Paper and paper fiber tend to be acidic and neutralize the caustic. By partially exchanging the partially neutralized caustic with fresher caustic, weaker caustic solutions can be utilized. Accordingly, one of the aspects of the improved process of our invention is removing anti-swelling chemical additives from sized paper and paperboard, and partially exchanging the partially neutralized caustic with fresher caustic.

Some results of our further laboratory work utilizing OCC are represented by the Fig. 2 graph of Tear Factor versus Breaking Length (i.e. Tensile) of the sheets made from the resulting fiber. The eight graphs in Figure 2. plot the TEAR FACTOR versus

BREAKING LENGTH results of eight Valley Beater test runs conducted on samples of OCC. Note that BREAKING LENGTH is a tensile property that describes TENSILE STRENGTH. Therefore the eight graphs are Tear-Tensile diagrams. Of these eight samples of OCC in Fig. 2, seven samples designated 250mm, 450mm, PO450mm, 600mm, 760mm, 761oldcor and 1000oldcor were compacted and treated by the process of our new invention as shown in the schematic labeled Fig. 3 as follows:

Before fibrillation in a Valley Beater each of the samples of compacted OCC **2** was placed in a laboratory size closed chamber **1** and the chamber was filled with a weak caustic solution **3**. Subsequently each sample was subjected to two cycles of consecutive additions **4** and removals **5** of weak caustic solution. The air in the compacted OCC acted in concert with the addition and removal of the weak caustic solution to circulate, flush and refresh weak caustic in and out of and within the compacted OCC. The process relied on the trapped air in the OCC to act as miniature pumps to circulate, flush and partially exchange the partially consumed weak caustic solution in the compacted OCC samples.

The eighth sample designated 25mm in Fig. 2 was processed in accordance with our prior patent 5,496,439 in which the process parameters were set such that very little air was trapped in the compacted OCC in the weak caustic solution in the closed chamber.

It is evident from Fig. 2. that the strength results of all eight tests are substantially the same within experimental error. There were two very important differences. First, it was observed that the weak caustic solution surrounding the compacted OCC turned dark during the circulating, flushing and refreshing of the weak caustic solution in the

compacted OCC in the processing of the seven samples processed in accordance with our new invention whereas there was very little darkening of the weak caustic solution during the processing of the eighth sample in which weak caustic solution replaced the air which had been removed in accordance with our prior patent 5,496,439 utilizing a first vacuum of only 25 mmHg absolute. Second, lower cost equipment requiring shorter processing time and consuming less energy are required to conduct the process steps of our new invention.

Table I. and the Fig. 4 graph of Air in Compacted OCC illustrate some results of our still further laboratory work utilizing OCC. The experiments were conducted to measure the pounds of air per ton of OCC first trapped in compacted OCC in the closed chamber during its processing. Table I. lists the data and tabulates the steps in the calculation of pounds of air per ton of OCC. Fig. 4 illustrates a straight line regression on semi-logarithm coordinates. It has been observed in these five experiments and in other laboratory experiments conducted after the preparation of our patent 5,496,439 that at conditions of weak caustic solution addition to and air removal from the closed chamber containing samples of OCC which resulted in greater than .09 pounds of air per ton of OCC trapped in the compacted OCC the weak caustic solution surrounding the compacted OCC turned dark during subsequent additions and removals of weak caustic solution whereas at conditions of weak caustic solution addition to and air removal from the closed chamber containing samples of OCC which resulted in less than .09 pounds of air per ton of OCC trapped in the compacted OCC the color of the weak caustic solution surrounding the compacted OCC remain relatively unchanged. There was a range of transition in color above and below .09 pounds of air per ton of

OCC. There was also a shifting of the transition value of .09 pounds of air per ton of OCC depending on the particular source and composition of the OCC of the various other the experiments.

Thus we have discovered that there are important improvements in the treatment of compacted OCC which can be a obtained by the process of our new invention which primarily circulates, flushes and partially exchanges the weak caustic solution in the compacted OCC compared to the process of our earlier inventions which primarily partially remove air from within and the compacted OCC and partially replace it with weak caustic solution. We have also discovered how to determine the amount of trapped air that is necessary to practice our new invention.

A loose analogy of our new invention could be drawn to the behavior of a kitchen sponge. It is only a loose analogy because a sponge's ability to pump liquids out of its mass resides in the elastic expansivity of its compressed solid matrix whereas the ability or our process to pump liquids out resides in the expansivity of the air trapped in the compacted waste material.

Fig. 5 titled Domains of Effectiveness of Our Prior "Remove & Replace" Inventions **7** and Our New "Circulate, Flush & Refresh" Invention **10** illustrates schematically these domains. In our previous inventions partial evacuation of air in the compacted material is limited by the deleterious affect of excessive evaporative drying of the fibers. The moisture conduct of good quality cellulosic fibers is about 6% to 7%. Reducing this moisture content enbrittles cellulosic fibers irreversibly weakening them and reducing their conformability and bondablity. This lower limit is illustrated in Fig. 5 by a light vertical line **6**. Lesser partial evacuation results in less replacement by a

debonding liquid that results in turn in less effective treatment **8**of the compacted waste material by treatment liquid replacement.

However un-replaced trapped air begins to contribute to the treatment benefits of circulating, flushing and refreshing the debonding liquid. A transition value of VA or PA is reached **9** beyond which circulating, flushing debonding liquid **10** are more effective than removing air from the compacted waste material and replacing it with debonding liquid **7**. This is the beginning of the domain in which our new invention **10** is more effective than our previous inventions **7**. The greater the amounts of debonding liquid added to and debonding liquid removed from the closed chamber, the more effective is the treatment provided by the process of our new invention. As greater amounts of debonding liquid are added to the compacted material with increased amounts of trapped air the energy to add the debonding liquid and the structural elements of the closed chamber, the access door(s), the valves, the accumulation pressure chambers and the high pressure pumps become increasingly expensive and cycle time can become longer. Thereby the cost-effectiveness diminishes **11** as illustrated in Fig. 5. The overlap of the two domains of effectiveness is illustrated in Fig. 2. where the quality of the fiber from the treatment is the same within experimental error.

There are two methods of controlling the schedules of adding a debonding liquid to the closed chamber. The first method utilizes process measurement instruments to calculate the mathematical value of the quantity $\{\Delta V_{12}/[W(1/p_1-1/p_2)]\}$ in which, during the first cycle of adding debonding liquid, p_1 is a first absolute pressure in pounds per square foot in the closed chamber at a first time and p_2 is a second absolute pressure in pounds per square foot in the closed chamber at a second time and ΔV_{12} is the volume

in cubic feet of debonding liquid added between the first time and the second time and W is the dry weight in pounds of the compacted waste material and equipment to control the addition of a debonding liquid into the closed chamber at a first schedule of flow rate and removing air from the closed chamber at a second schedule of flow rate such that the mathematical quantity is at least the value VA. The value VA is determined in the laboratory as described above. The value VA we measured and concluded from laboratory observations is 1.27 feet for the OCC that we evaluated.

The second method which is more approximate is to control the addition of a debonding liquid into the closed chamber at a first schedule of flow rate and removal air from the closed chamber at a second schedule of flow rate such that the average pressure at the midpoint in the closed chamber is PA. The value PA is 160 mmHg absolute for the OCC that we evaluated.

It is apparent to those skilled in the art that other Treatment Fluids, which provide other recovered fiber improvements, can be utilized in the process of our invention. Other recovered fiber improvements can include fiber bleaching, fiber coloration, fiber deinking, fiber deodorizing and fiber-plastic debonding. Although less effective, it is also apparent to those skilled in the art that other, non-miscible fluids can be utilized in the consecutive cycles of adding to and removing from the closed chamber. This less effective use of non-miscible fluids would require that the closed chamber be constructed such that the Treatment Fluid not uncover the compacted material until the treatment process is completed.